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Yip et al.

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(54) **METHOD OF MAKING SOLDER PAD**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 8 days.

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(22) Filed: **Apr. 22, 2007**

(65) **Prior Publication Data**

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H01L 21/44 (2006.01)

(52) **U.S. Cl.** **438/612**; 438/107; 438/112; 438/121; 438/124; 438/638; 257/E21.476

(58) **Field of Classification Search** ..... 438/456, 438/612, 613, 669, 687, 700, 702, 703, 942, 438/FOR. 132, FOR. 133
See application file for complete search history.

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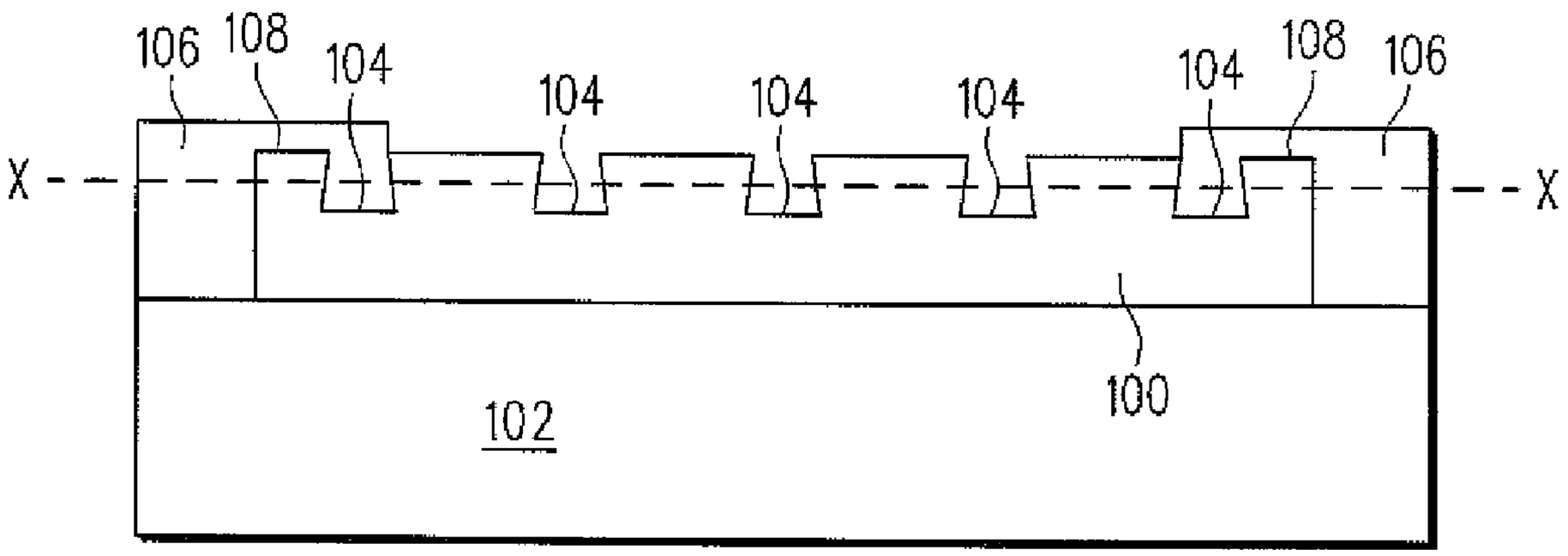
(57) **ABSTRACT**

A method of making a solder pad includes providing a substrate having a metal layer formed on it, and applying a photo resist to the metal layer. The photo resist is patterned. A first etching operation is performed on the metal layer to form voids in the metal layer. A second etching operation is performed on the metal layer to form the solder pad. A solder mask is formed on the substrate and a portion of the solder pad.

14 Claims, 6 Drawing Sheets



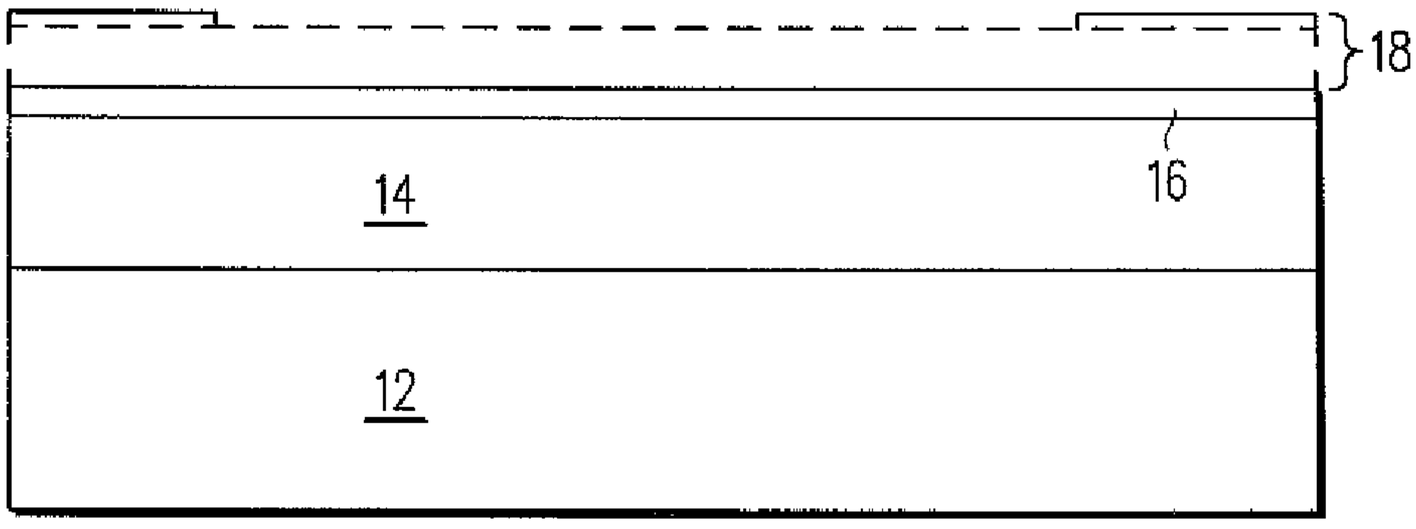


FIG. 1
-PRIOR ART-

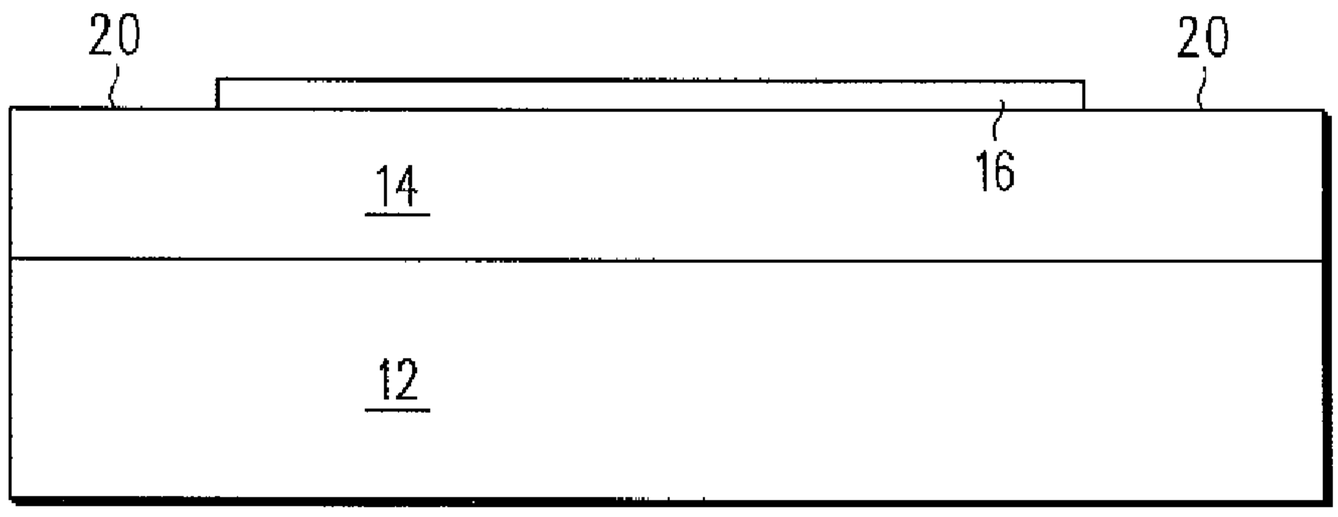


FIG. 2
-PRIOR ART-

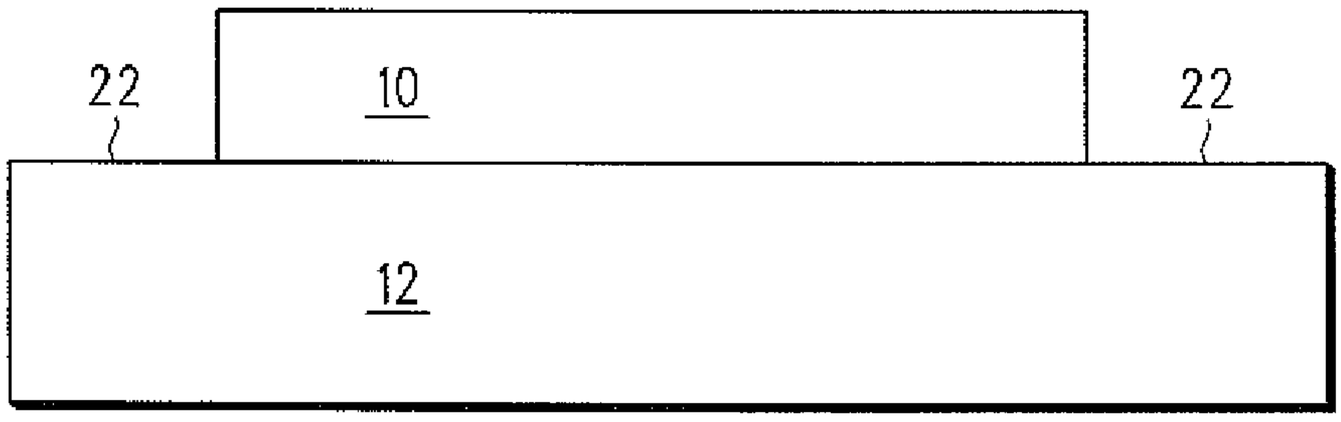


FIG. 3
-PRIOR ART-

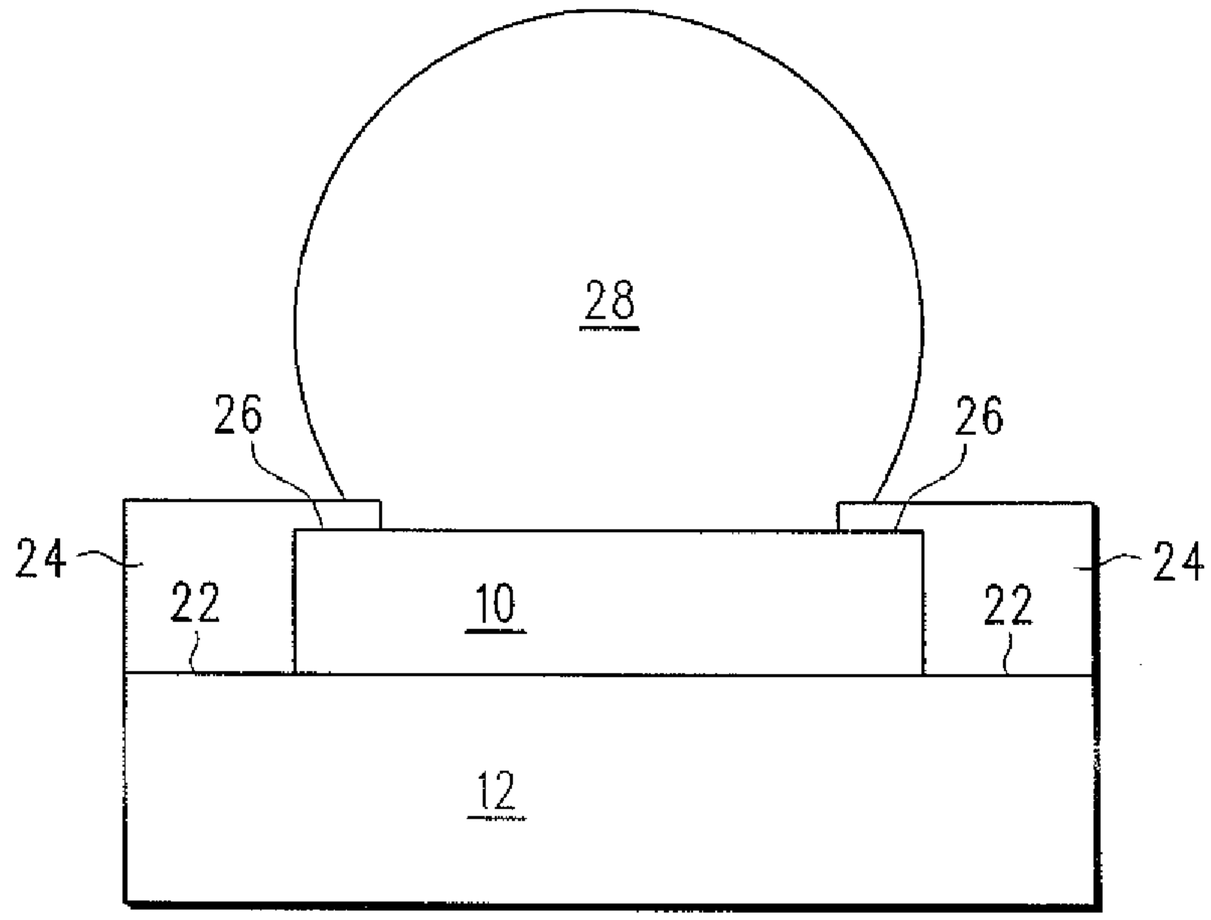


FIG. 4
-PRIOR ART-

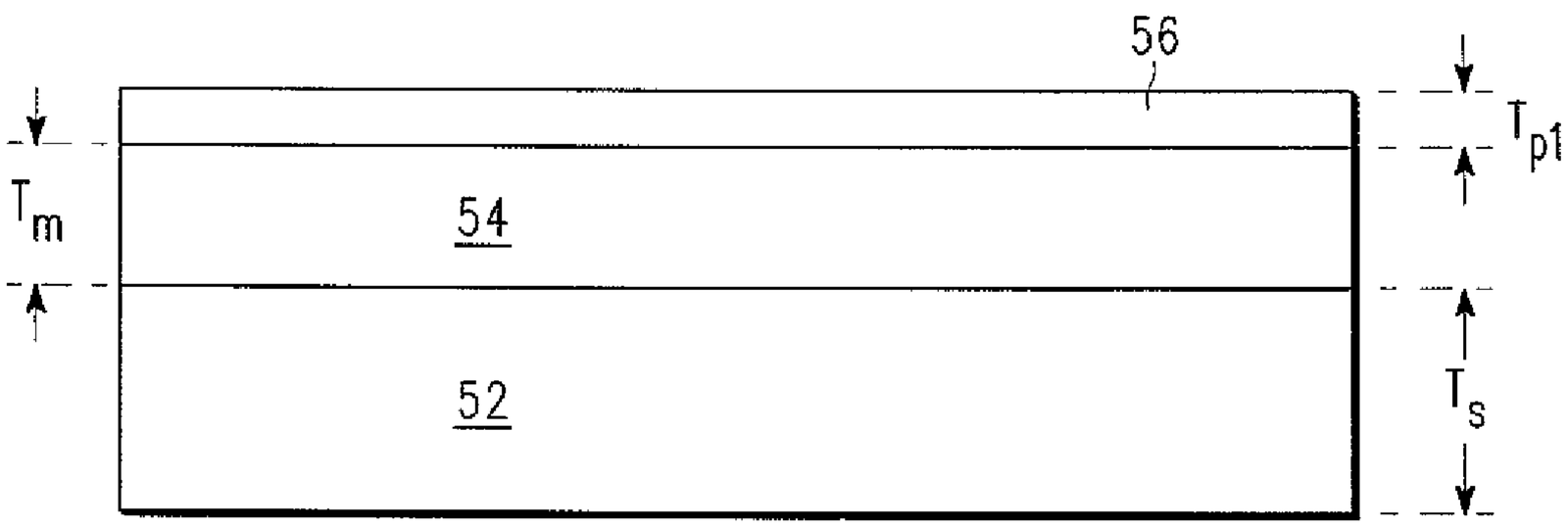


FIG. 5

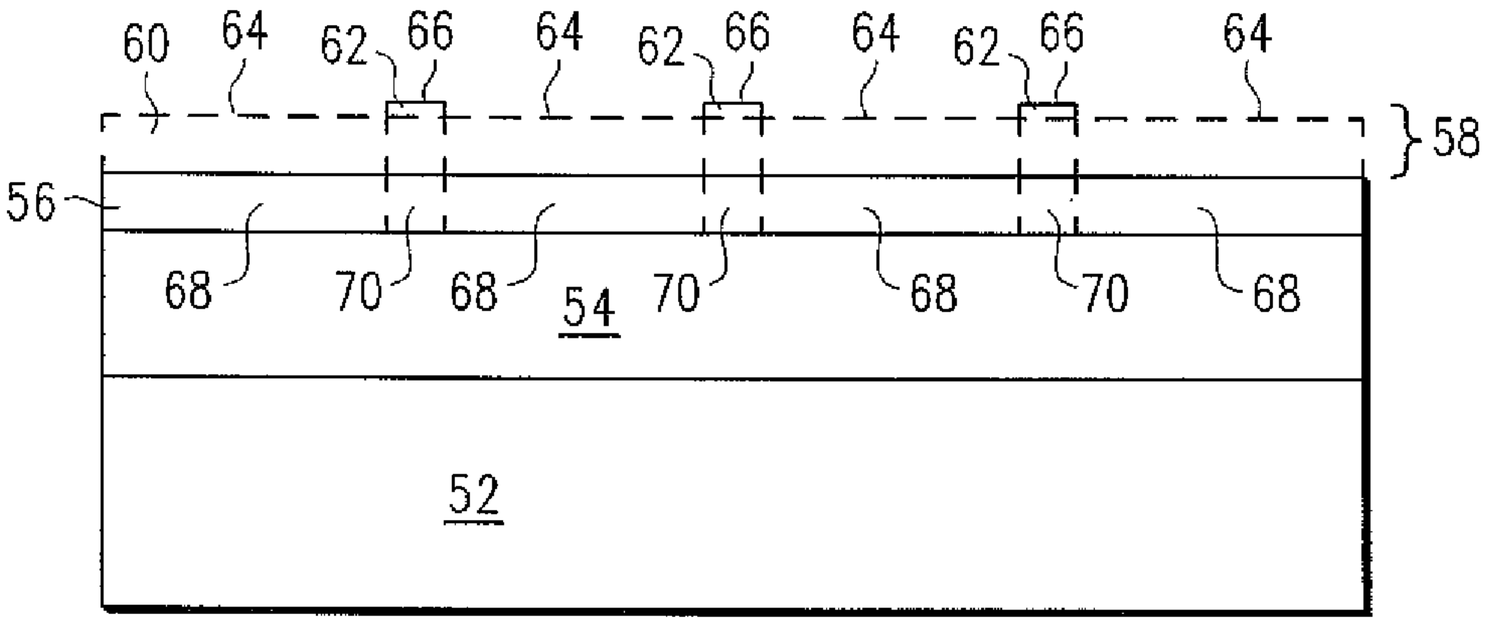


FIG. 6

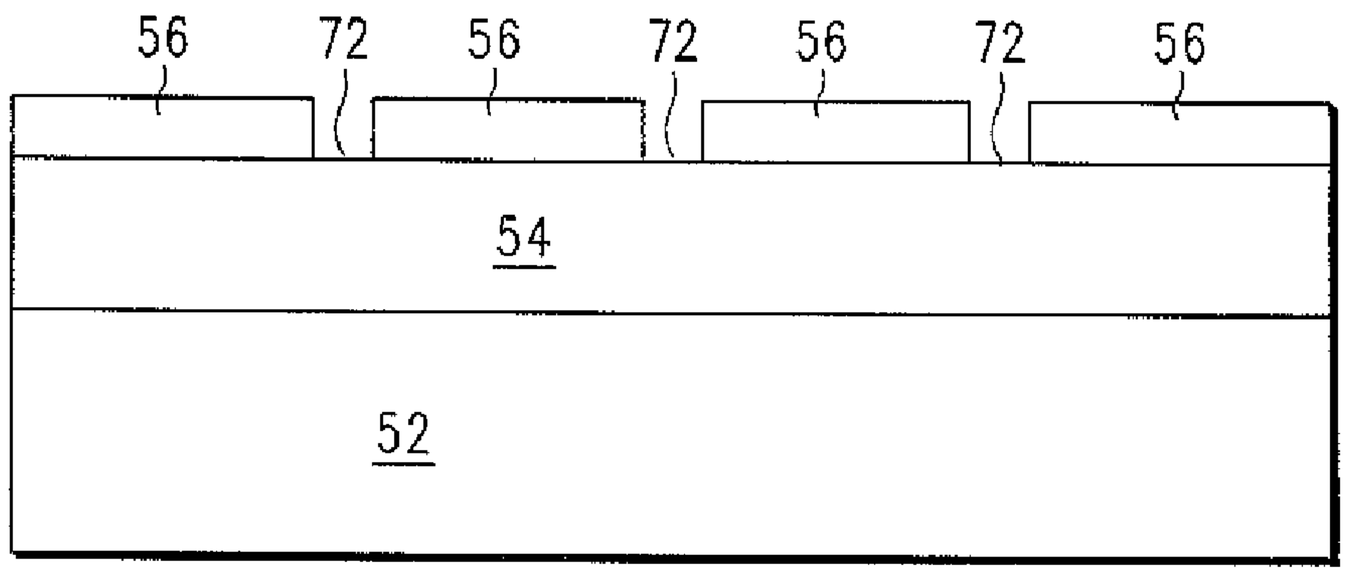


FIG. 7

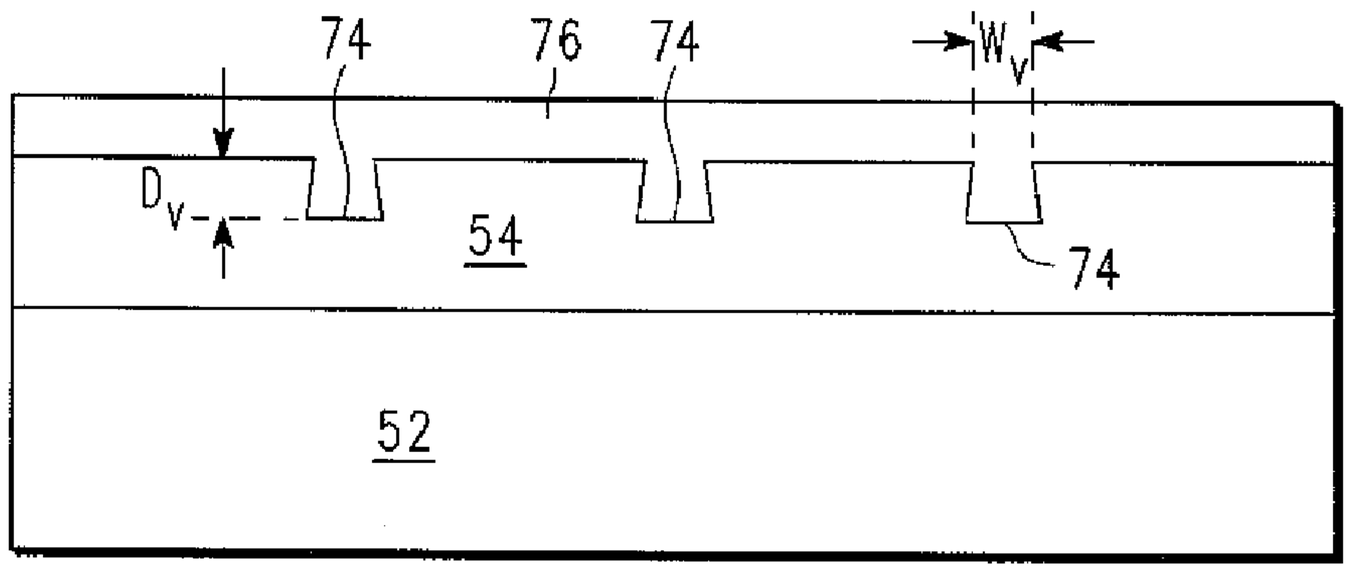


FIG. 8

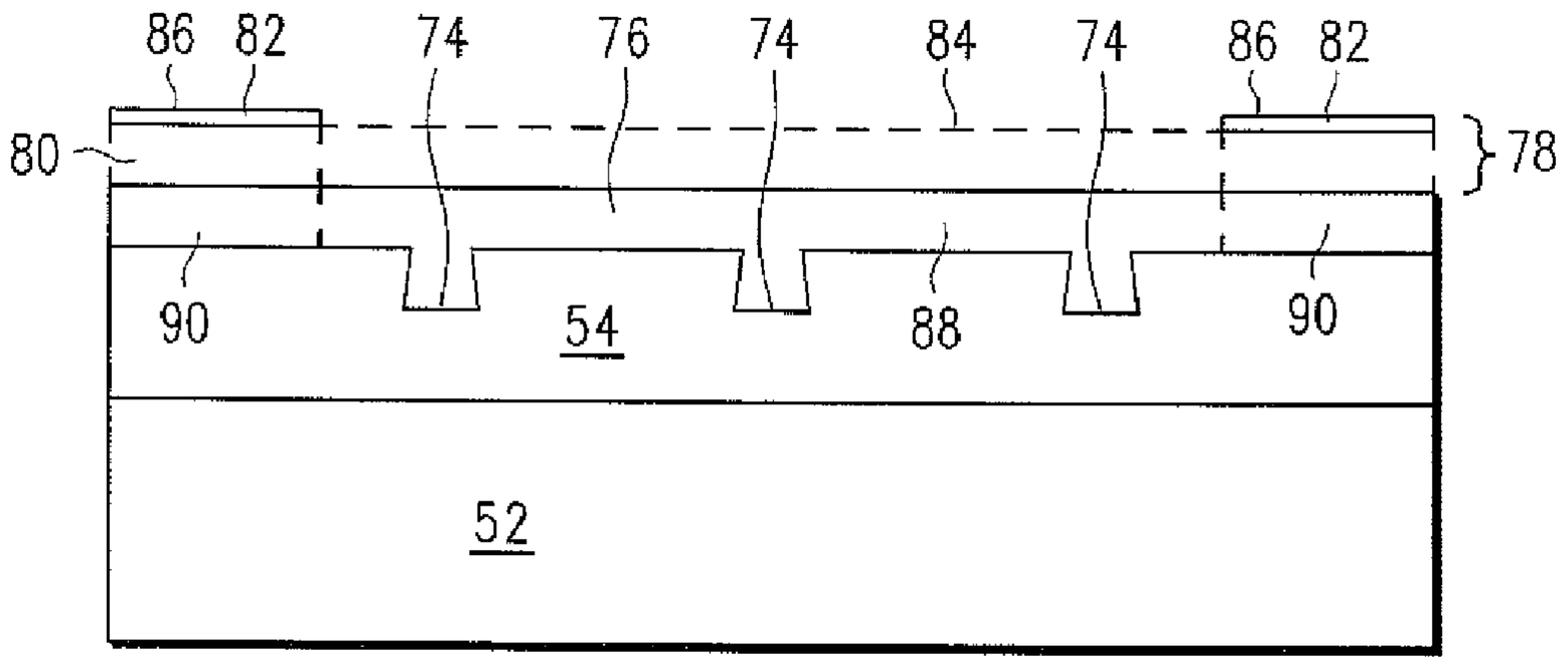


FIG. 9

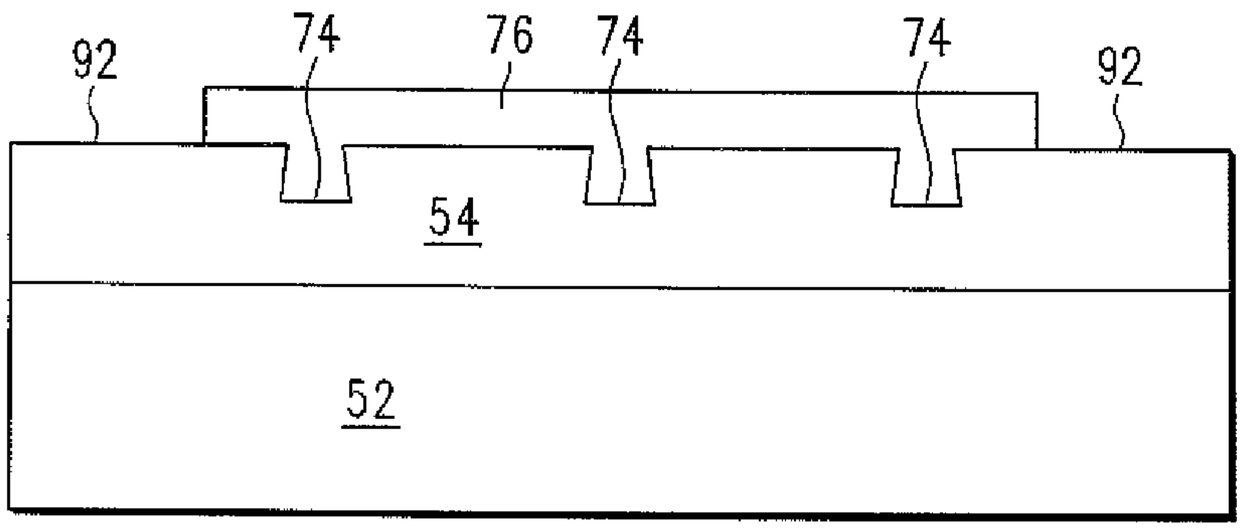


FIG. 10

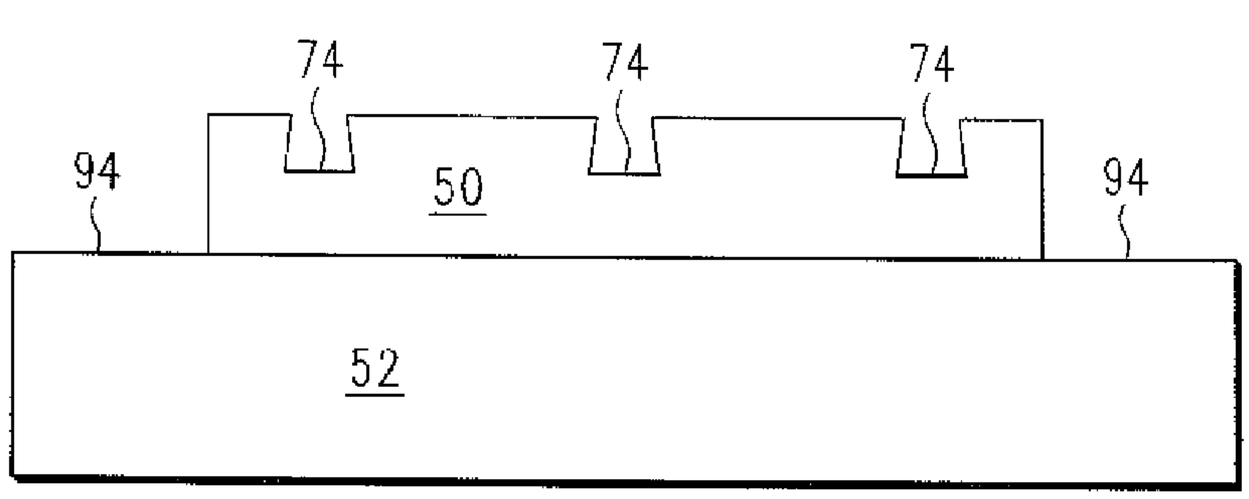


FIG. 11

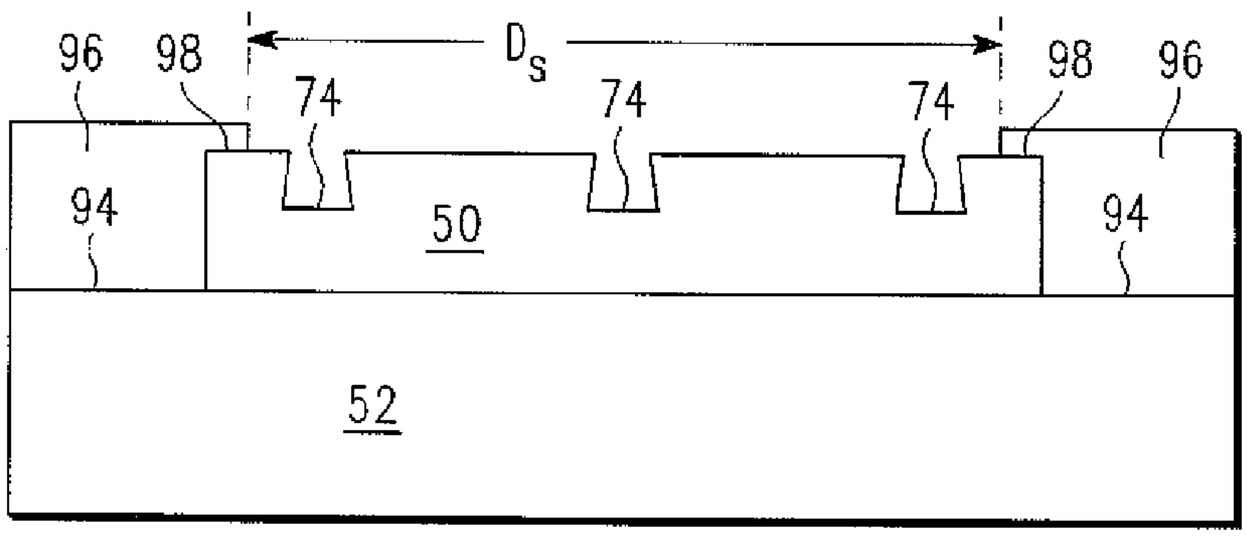


FIG. 12

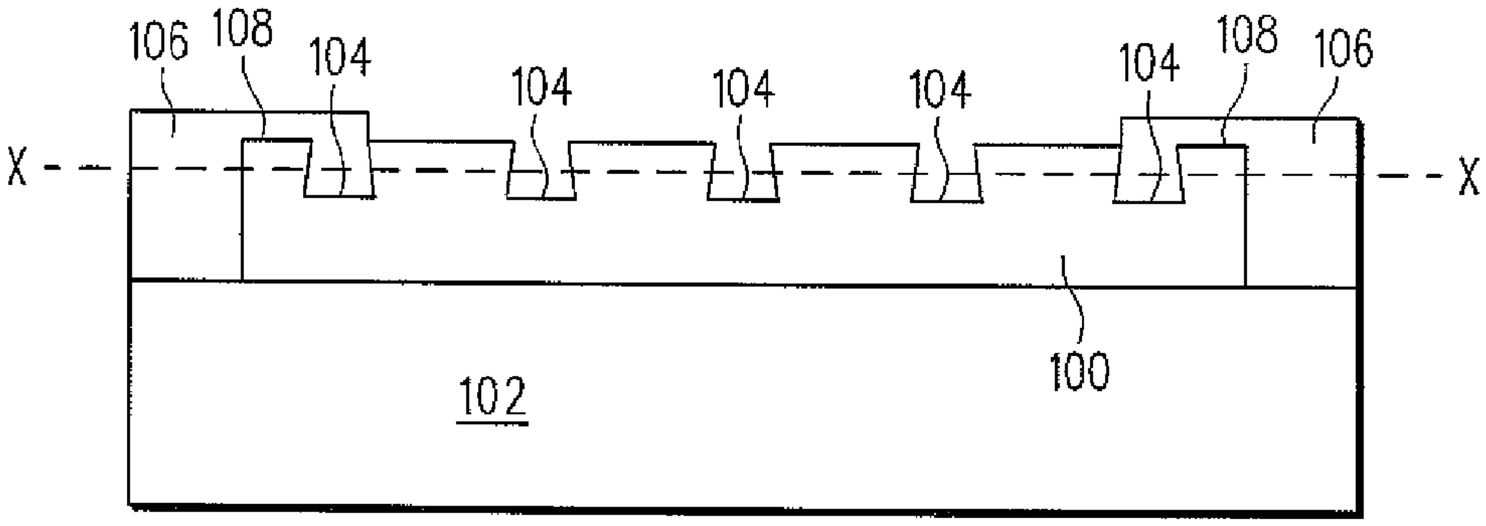


FIG. 13

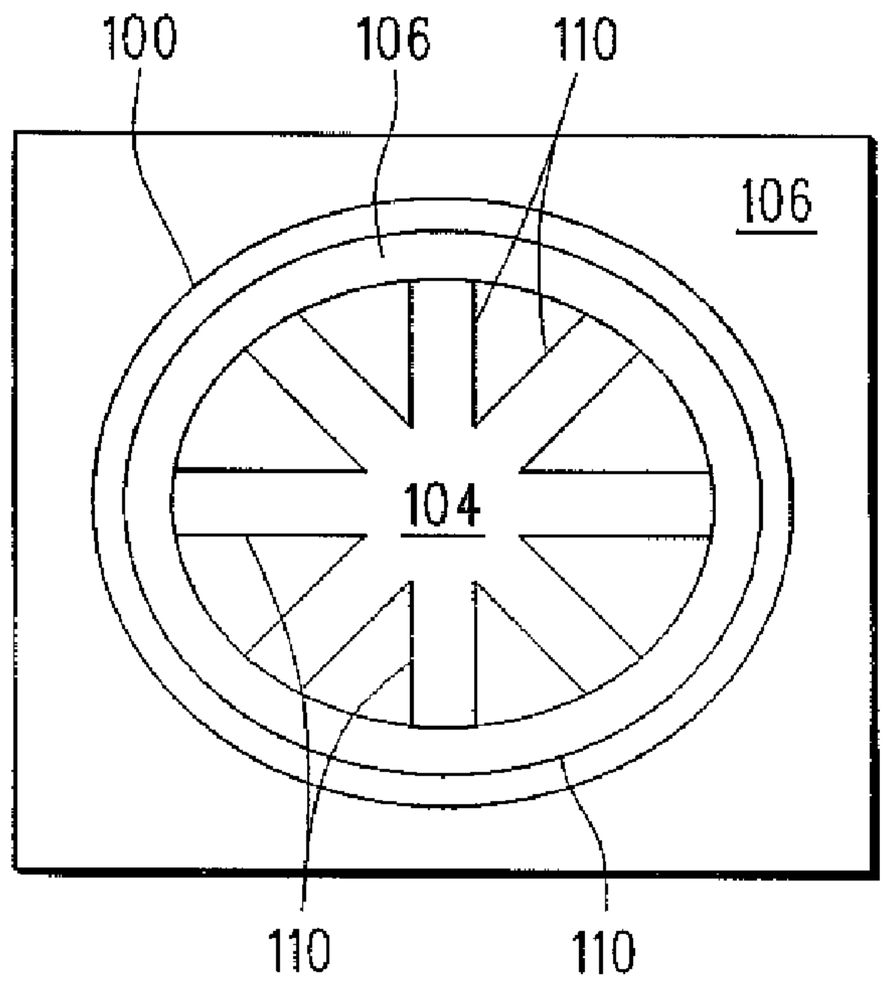


FIG. 14

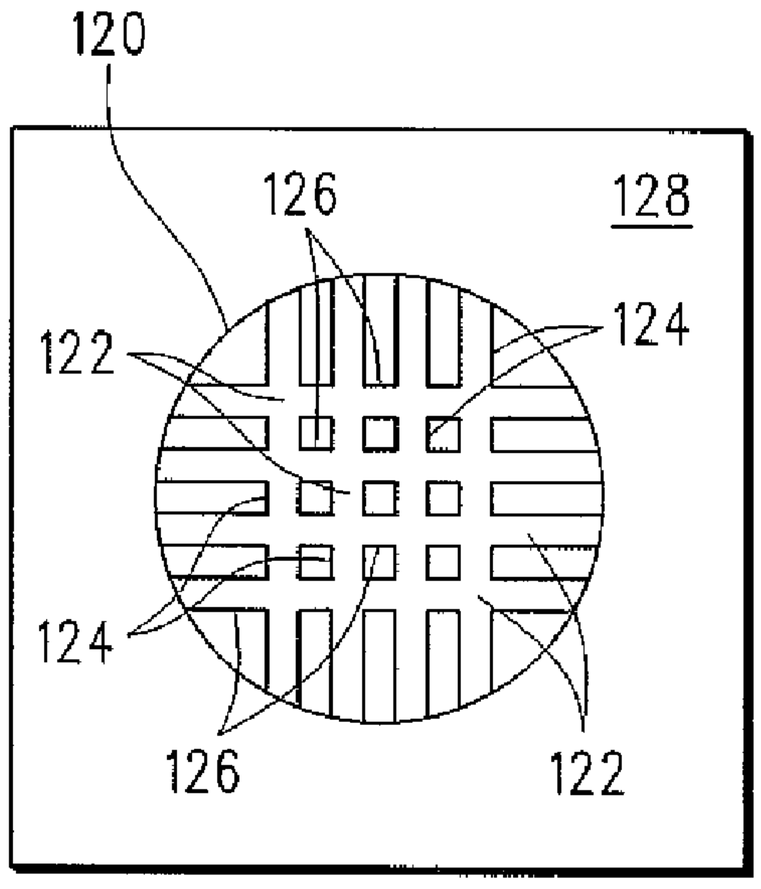


FIG. 15

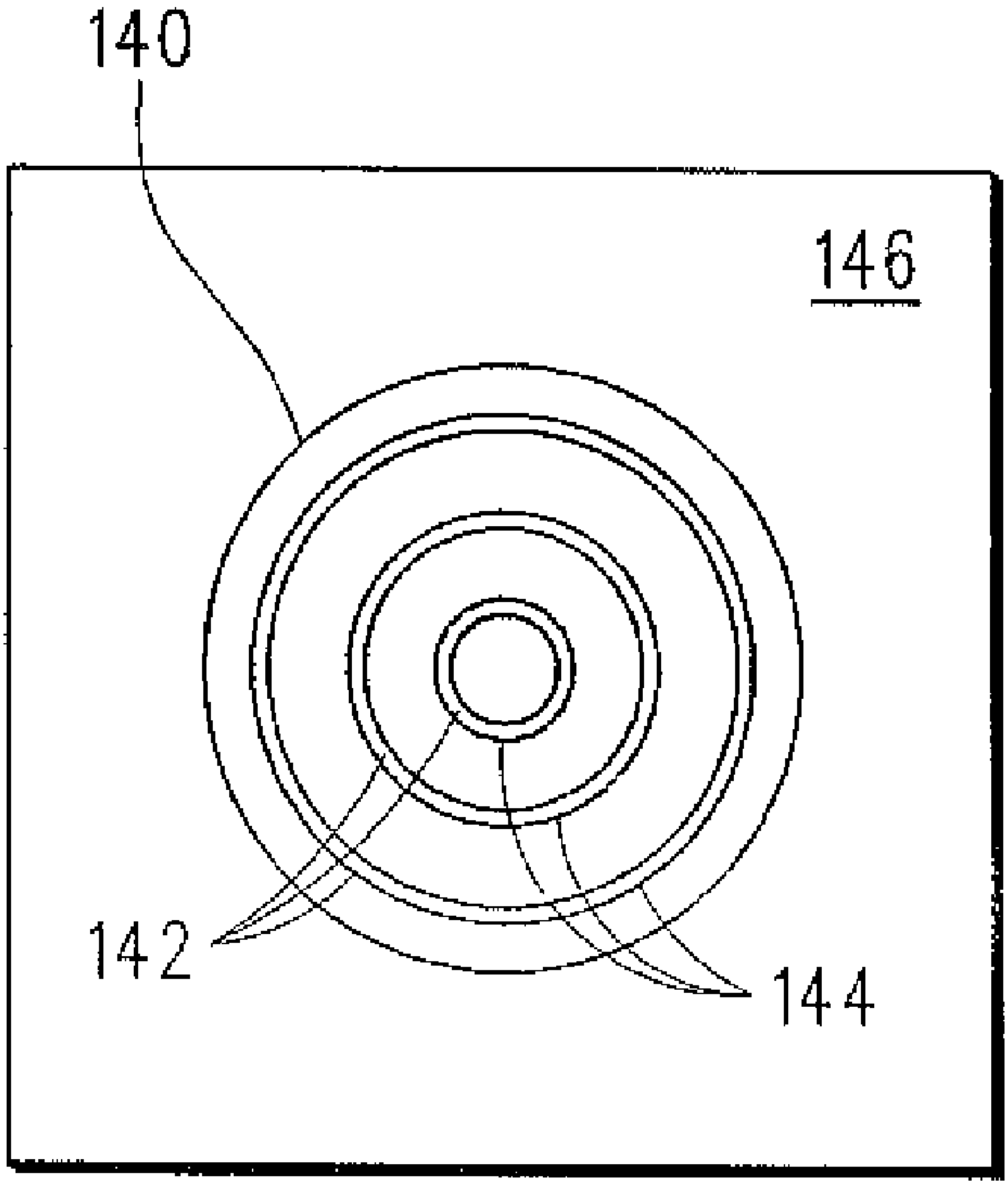


FIG. 16

METHOD OF MAKING SOLDER PAD

BACKGROUND OF THE INVENTION

The present invention relates to integrated circuits, and more particularly, to a method of making a solder pad for an integrated circuit.

Solder pads provide both electrical and mechanical connections, as well as a thermal path, between electronic components. Typically, solder balls or bumps are deposited onto the solder pads and reflowed to form respective solder joints between the electronic components. A conventional method of making a solder pad **10** will now be described with reference to FIGS. **1** through **4**. Referring now to FIG. **1**, a substrate **12** having a metal layer **14** formed thereon is shown. A photo resist **16** is applied to the metal layer **14** and exposed through a photo mask **18** placed over the photo resist **16**. Referring now to FIG. **2**, the photo mask **18** is removed after exposure and the photo resist **16** is developed, exposing portions **20** of the metal layer **14**. Referring now to FIG. **3**, the metal layer **14** is selectively etched through the developed photo resist **16** to form the solder pad **10**. As shown in FIG. **3**, portions **22** of the substrate **12** are exposed by the etching operation. Referring now to FIG. **4**, a solder mask **24** is formed on the exposed portions **22** of the substrate **12** and a portion **26** of the solder pad **10**. A solder ball or bump **28** is deposited on the solder pad **10**. Because the reliability of the solder joints formed between the electronic components is dependent on the adhesion of the solder ball **28** to the solder pad **10**, there is a need for strong adhesion between the solder pad **10** and the solder ball **28** deposited thereon.

It would be desirable to have a method of making a solder pad that enhances adhesion of the solder ball to the solder pad.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description of a preferred embodiment of the invention will be better understood when read in conjunction with the appended drawings. The present invention is illustrated by way of example and is not limited by the accompanying figures, in which like references indicate similar elements. It is to be understood that the drawings are not to scale and have been simplified for ease of understanding the invention.

FIGS. **1** through **4** illustrate a conventional method of making a solder pad;

FIG. **5** is an enlarged cross-sectional view of a substrate having a metal layer formed thereon in accordance with an embodiment of the present invention;

FIG. **6** is an enlarged cross-sectional view of a first photo mask placed over a first photo resist applied to the metal layer of FIG. **5**;

FIG. **7** is an enlarged cross-sectional view of the first photo resist of FIG. **6** after a patterning operation;

FIG. **8** is an enlarged cross-sectional view of a plurality of voids formed in the metal layer of FIG. **7**;

FIG. **9** is an enlarged cross-sectional view of a second photo mask placed over a second photo resist applied to the metal layer of FIG. **8**;

FIG. **10** is an enlarged cross-sectional view of the second photo resist of FIG. **9** after a patterning operation;

FIG. **11** is an enlarged cross-sectional view of a solder pad formed out of the metal layer of FIG. **10**;

FIG. **12** is an enlarged cross-sectional view of a solder mask formed on the substrate and a portion of the solder pad of FIG. **11**;

FIG. **13** is an enlarged cross-sectional view of a solder pad made in accordance with another embodiment of the present invention;

FIG. **14** is an enlarged top plan view of the solder pad of FIG. **13** along a plane X-X;

FIG. **15** is an enlarged top plan view of a solder pad in accordance with one embodiment of the present invention; and

FIG. **16** is an enlarged top plan view of a solder pad in accordance with another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The detailed description set forth below in connection with the appended drawings is intended as a description of the presently preferred embodiments of the invention, and is not intended to represent the only form in which the present invention may be practiced. It is to be understood that the same or equivalent functions may be accomplished by different embodiments that are intended to be encompassed within the spirit and scope of the invention. In the drawings, like numerals are used to indicate like elements throughout.

The present invention provides a method of making a solder pad including the step of providing a substrate having a metal layer formed thereon. A photo resist is applied to the metal layer and patterned. A first etching operation is performed on the metal layer to form a plurality of voids in the metal layer. A second etching operation is performed on the metal layer to form the solder pad. A solder mask is formed on the substrate and a portion of the solder pad. The present invention also provides a solder pad made in accordance with the method described above.

The present invention further provides a method of making a solder pad including the step of providing a substrate having a metal layer formed thereon. A first photo resist is applied to the metal layer and patterned. A first etching operation is performed on the metal layer to form a plurality of voids in the metal layer. A second photo resist is applied to the metal layer and patterned. A second etching operation is performed on the metal layer to form the solder pad. A solder mask is formed on the substrate and a portion of the solder pad.

The present invention also provides a method of making a solder pad including the step of providing a substrate having a metal layer formed thereon. A first photo resist is applied to the metal layer. The first photo resist is exposed through a first photo mask and developed. A first etching operation is performed on the metal layer to form a plurality of voids in the metal layer. A second photo resist is applied to the metal layer. The second photo resist is exposed through a second photo mask and developed. A second etching operation is performed on the metal layer to form the solder pad. A solder mask is formed on the substrate and a portion of the solder pad.

FIGS. **5** through **12** illustrate a method of making a solder pad **50** in accordance with an embodiment of the present invention.

Referring now to FIG. **5**, a substrate **52** having the metal layer **54** formed thereon is provided as shown. A first photo resist **56** is applied to the metal layer **54**. The substrate **52** may be a bismaleimide-triazine (BT) substrate, as is commonly used in semiconductor packaging. The metal layer **54** is formed on the substrate **52** via a well known metal deposition process such as, for example, sputtering or vacuum evaporation. In one embodiment, the metal layer **54** comprises copper (Cu). The first photo resist **56** may be any known photo resist

material and is applied to the metal layer **54** using a well known photo resist application technique such as roll coating in the case of a dry film resist. In one embodiment, the substrate **52** has a thickness T_s of about 0.2 to 0.60 millimeters (mm), the metal layer **54** has a thickness T_m of about 0.05 mm, and the first photo resist **56** has a thickness T_{p1} of about 0.10 mm.

FIGS. **6** and **7** illustrate a patterning process performed on the first photo resist **56**.

Referring now to FIG. **6**, a first photo mask **58** is placed over the first photo resist **56** as shown. The first photo resist **56** is exposed through the first photo mask **58**.

The first photo mask **58** comprises a transparent plate **60** (defined by dashed lines) of glass or quartz, for example, on which a first pattern to be transferred onto the metal layer **54** is formed using an opaque material **62** such as, for example, chrome. Accordingly, a top surface of the first photo mask **58** comprises transparent areas **64** (defined by dashed lines) and opaque areas **66** (defined by solid lines). The transparent and opaque areas **64** and **66** on the top surface of the first photo mask **58** define the first pattern to be formed in the metal layer **54**.

Depending on the type of photo resist used, the first photo resist **56** is exposed to either ultraviolet (UV) light or laser generated light. In the embodiment shown, the first photo resist **56** is a negative-working photo resist, that is, exposed portions **68** of the first photo resist **56** polymerize or harden when irradiated. Unexposed portions **70** of the first photo resist **56** do not polymerize and are soluble when immersed in chemical solvents. Nonetheless, those of skill in the art will understand that the present invention is not limited to negative-working photo resists. For example, the first photo resist **56** may instead be a positive-working photo resist whose exposed portions **68** become unpolymerized when irradiated.

Referring now to FIG. **7**, the first photo mask **58** is removed and the first photo resist **56** is developed. The unexposed, and therefore unpolymerized, portions **70** of the first photo resist **56** are dissolved away during the development process, thereby forming a negative image of the first photo mask **58** in the first photo resist **56**. As shown in FIG. **7**, portions **72** of the metal layer **54** are exposed by the development process.

In one embodiment, the first photo resist **56** is developed by passing the substrate **52**, the metal layer **54** and the first photo resist **56** between spray banks of a chemical solvent such as, a heated dilute solution of sodium or potassium carbonate. Nonetheless, those of skill in the art will understand that the present invention is not limited to a particular method of developing the first photo resist **56** or by the chemicals used in the development process.

Referring now to FIG. **8**, a plurality of voids **74** is formed in the metal layer **54** as shown. The voids **74** are formed by performing a first etching operation on the metal layer **54**, and more particularly by half-etching the metal layer **54** through the first photo resist **56**. Accordingly, a pattern substantially identical to that of the first photo mask **58** is formed in the metal layer **54**. The first photo resist **56** is removed from the metal layer **54** after the first etching operation. A second photo resist **76** is applied to the metal layer **54**. As shown in FIG. **8**, the second photo resist **76** fills the voids **74** formed in the metal layer **54**.

A known etching technique such as, for example, wet etching or dry etching may be used to etch the metal layer **54**. In the embodiment shown, the voids **74** have a substantially trapezoidal cross-section. Nonetheless, it will be understood by those of skill in the art that the present invention is not limited by the cross-sectional shape of the voids **74**. For example, the voids **74** may have a substantially rectangular cross-section in other embodiments. The voids **74** with the substantially trapezoidal cross-section may be formed by over-etching the metal layer **54**. In one embodiment, the voids **74** have a depth D_v of about 0.02 mm and a width W_v of about 0.015 mm.

The first photo resist **56** may be removed from the metal layer **54** using a chemical solvent such as acetone. Such solvents are widely used and commercially available.

The second photo resist **76** may be any known photo resist material and is applied to the metal layer **54** using a well known photo resist application technique such as roll coating in the case of a dry film resist. In one embodiment, the second photo resist **76** has a thickness T_{p2} of about 0.1 mm.

FIGS. **9** and **10** illustrate a patterning process performed on the second photo resist **76**.

Referring now to FIG. **9**, a second photo mask **78** is placed over the second photo resist **76** as shown. The second photo resist **76** is exposed through the second photo mask **78**.

The second photo mask **78** comprises a transparent plate **80** (defined by dashed lines) of glass or quartz, for example, on which a second pattern to be transferred onto the metal layer **54** is formed using an opaque material **82** such as, for example, chrome. Accordingly, a top surface of the second photo mask **78** comprises a transparent area **84** (defined by dashed lines) and opaque areas **86** (defined by solid lines). The transparent and opaque areas **84** and **86** on the top surface of the second photo mask **78** define the second pattern to be formed in the metal layer **54**.

Depending on the type of photo resist used, the second photo resist **56** is exposed to either ultraviolet (UV) light or laser. In the embodiment shown, the second photo resist **76** is a negative-working photo resist, that is, exposed portions **88** of the second photo resist **76** polymerize or harden when irradiated. Unexposed portions **90** of the second photo resist **76** do not polymerize and are soluble when immersed in chemical solvents. Nonetheless, as previously mentioned, those of skill in the art will understand that the present invention is not limited to negative-working photo resists. In an alternative embodiment, the second photo resist **76** may be a positive-working photo resist whose exposed portions **88** become unpolymerized when irradiated.

Referring now to FIG. **10**, the second photo mask **78** is removed and the second photo resist **76** is developed. The unexposed, and therefore unpolymerized, portions **90** of the second photo resist **76** are dissolved away during the development process, thereby forming a negative image of the second photo mask **78** in the second photo resist **76**. As shown in FIG. **10**, portions **92** of the metal layer **54** are exposed by the development process.

In one embodiment, the second photo resist **76** is developed by passing the substrate **52**, the metal layer **54** and the second photo resist **76** between spray banks of a chemical solvent such as, for example, a heated dilute solution of sodium or potassium carbonate. Nonetheless, those of skill in the art will understand that the present invention is not limited to a particular method of developing the second photo resist **76** or by the chemicals used in the development process.

Referring now to FIG. **11**, a second etching operation is performed on the metal layer **54** to form the solder pad **50**. More particularly, the solder pad **50** is formed by etching the metal layer **54** through the second photo resist **76**. As shown in FIG. **11**, portions **94** of the substrate **52** are exposed by the second etching operation. The second photo resist **76** is removed from the metal layer **54** after the etching operation. A known etching technique such as, for example, wet etching or dry etching may be used to etch the metal layer **54**. The

second photo resist **76** may be removed with a commercially available chemical solvent such as acetone.

Referring now to FIG. **12**, a solder mask **96** is formed on the exposed portions **94** of the substrate **52** and a portion **98** of the solder pad **50** as shown. Subsequent to the solder masking process, solder material in the form of a solder ball or bump, for example, may be deposited onto the solder pad **50**.

The solder mask **96** protects predetermined areas of the substrate **52** from solder deposition, preventing deposition of the solder material onto circuit features other than the solder pad **50**. A well known solder mask coating operation such as, for example, screen printing, may be used to form the solder mask **96** on the substrate **52** and the solder pad **50**. In one embodiment, the uncovered solder pad **50** has a diameter D_s (or width if rectangular) of about 0.02 mm.

The voids **74** in the solder pad **50** increase the area of contact between the solder pad **50** and the solder material deposited thereon. The increase in contact area enhances adhesion of the solder material to the solder pad **50**, thereby reducing the incidence of brittle fracture and solder ball drop. Additionally, the increase in contact area between the solder pad **50** and the solder material also enhances thermal and electrical conductivity between electronic components. Mechanical adhesion of the solder material to the solder pad **50** is further enhanced by the provision of an interlocking mechanism in the form of the substantially trapezoidal cross-section of the voids **74**.

Although FIGS. **6** and **9** show the first and second photo resists **56** and **76** being patterned with the first and second photo masks **58** and **78**, respectively, it will be understood that the present invention is not limited to patterning methods employing photo masks. In alternative embodiments, the first and second photo resists **56** and **76** may be patterned using a maskless patterning method such as, for example, a patterning method employing an electron beam.

Referring now to FIG. **13**, an enlarged cross-sectional view of a solder pad **100** in accordance with another embodiment of the present invention is shown. The solder pad **100** is formed on a substrate **102** and includes a plurality of voids **104**. A solder mask **106** is formed on the substrate **102** and a portion **108** of the solder pad **100** such that the solder mask **106** fills one or more of the voids **104** in the solder pad **100**. Filling of one or more of the voids **104** with solder mask material enhances adhesion of the solder mask **106** to the solder pad **100**.

Referring now to FIG. **14**, an enlarged top plan view of the solder pad **100** along a plane X-X in FIG. **13** is shown. As shown in FIG. **14**, the voids **104** in the solder pad **100** define a plurality of channels **110** extending across a surface of the solder pad **100**. In the embodiment shown, the channels **110** are defined in a radial pattern and thus intersect at a center of the solder pad **100**.

Referring now to FIG. **14**, an enlarged, top plan view of a solder pad **120** in accordance with an embodiment of the present invention is shown. The solder pad **120** includes a plurality of voids **122** formed therein. The voids **122** define a plurality of channels **124** and **126** extending across a surface of the solder pad **120**. A solder mask **128** is formed over a portion of the solder pad **120**. As shown in FIG. **15**, the channels **124** and **126** are defined by a plurality of lines: a first set of substantially parallel lines **124** and a second set of substantially parallel lines **126**. In the embodiment shown, the first and second sets of lines **124** and **126** intersect.

Referring now to FIG. **16**, an enlarged top plan view of a solder pad **140** in accordance with another embodiment of the present invention is shown. The solder pad **140** includes a plurality of voids **142** formed therein, the voids **142** defining a plurality of channels **144** extending across a surface of the solder pad **140**. A solder mask **146** is formed over a portion of the solder pad **140**. In the embodiment shown, the channels **144** are defined in a concentric pattern.

As is evident from the foregoing discussion, the present invention provides a method of making a solder pad with improved adhesive properties. The provision of voids in the solder pad increases the surface area of contact between the solder pad and solder material (e.g., a solder ball or bump) deposited thereon. The increase in contact area enhances adhesion of the solder material to the solder pad, thereby reducing the incidence of brittle fracture and solder ball drop. Furthermore, the increase in contact area between the solder pad and the solder material enhances thermal and electrical conductivity between electronic components. Additionally, the substantially trapezoidal cross-section of the voids functions as an interlocking mechanism, providing mechanical adhesion between the solder pad and the solder material deposited thereon.

The description of the preferred embodiments of the present invention have been presented for purposes of illustration and description, but are not intended to be exhaustive or to limit the invention to the forms disclosed. It will be appreciated by those skilled in the art that changes could be made to the embodiments described above without departing from the broad inventive concept thereof. For example, the present invention may be applied to ball grid array (BGA) packages or any solderable surfaces. It is understood, therefore, that this invention is not limited to the particular embodiments disclosed, but covers modifications within the spirit and scope of the present invention as defined by the appended claims.

The invention claimed is:

1. A method of making a solder pad, comprising the steps of:

providing a substrate having a metal layer formed thereon;

applying a photoresist to the metal layer;

patterning the photo resist;

performing a first etching operation on the metal layer to form a plurality of voids in the metal layer, wherein the voids are formed by half-etching the metal layer and wherein the voids define a plurality of channels extending across a surface of the solder pad, and wherein the channels are defined in one of a radial pattern and a concentric pattern;

performing a second etching operation on the metal layer to form the solder pad; and

forming a solder mask on the substrate and a portion of the solder pad.

2. The method of making a solder pad according to claim **1**, wherein the voids have a depth of about 0.02 mm.

3. The method of making a solder pad according to claim **2**, wherein the voids have a width of about 0.015 mm.

4. The method of making a solder pad according to claim **1**, wherein the voids have a substantially trapezoidal cross-section.

5. The method of making a solder pad according to claim **4**, wherein the voids are formed by over-etching the metal layer.

6. The method of making a solder pad according to claim **1**, wherein the substrate is a bismaleimide-triazine (BT) substrate.

7. The method of making a solder pad according to claim **1**, wherein the metal layer comprises copper (Cu)

8. The method of making a solder pad according to claim **1**, wherein the step of patterning the photo resist comprises exposing the photo resist through a photo mask.

9. The method of making a solder pad according to claim 8, wherein the step of patterning the photo resist further comprises developing the photo resist.

10. The method of making a solder pad according to claim 1, further comprising removing the photoresist from the metal layer after the etching operations.

11. The method of making a solder pad according to claim 1, wherein the solder mask fills one or more of the voids.

12. A solder pad made in accordance with the method of claim 1.

13. A method of making a solder pad, comprising the steps of:

providing a substrate having a metal layer formed thereon;

applying a photoresist to the metal layer;

patterning the photo resist;

performing a first etching operation on the metal layer to form a plurality of voids in the metal layer, wherein the voids are formed by half-etching the metal layer such that the voids define a plurality of channels extending across a surface of the solder pad, and wherein the channels are defined by a plurality of lines;

performing a second etching operation on the metal layer to form the solder pad; and

forming a solder mask on the substrate and a portion of the solder pad.

14. A method of making a solder pad, comprising the steps of:

providing a substrate having a metal layer formed thereon;

applying a photoresist to the metal layer;

patterning the photo resist;

performing a first etching operation on the metal layer to form a plurality of voids in the metal layer, wherein the voids are formed by half-etching the metal layer such that the voids define a plurality of channels extending across a surface of the solder pad, and wherein the channels are defined by a plurality of lines and wherein one or more of the lines intersect;

performing a second etching operation on the metal layer to form the solder pad; and

forming a solder mask on the substrate and a portion of the solder pad.

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